Developing an Undergraduate Education Pipeline into Orthopaedic Research

Christopher J. Panebianco[1], Mili Shah[2], Woojin M. Han[3], James C. Iatridis[3], Andrea J. Vernengo[4], Jennifer R. Weiser[5]
[1]Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, PA, USA
[2]Department of Mathematics, The Cooper Union for the Advancement of Science and Art, New York, NY, USA
[3]Leni and Peter W. May Department of Orthopaedics, Icahn School of Medicine at Mount Sinai, New York, NY, USA
[4]Department of Chemical Engineering, Rowan University, Glassboro, NJ, USA
[5]Department of Chemical Engineering, The Cooper Union for the Advancement of Science and Art, New York, NY, USA

INTRODUCTION: As our understanding of STEM education pedagogy and student learning styles is deepening, developing sustainable tools to help students participate in complex research has become more necessary. Hands-on educational experiences at the early stages of an undergraduate program are seminal in propelling students into STEM research fields long-term.[1] Additionally, hands-on experiences are a way to engage undergraduate and K-12 students in a variety of seemingly complex STEM topics, such as the field of biomaterials in relation to orthopaedics. To address the growing need for researchers in the field of biomaterial-based orthopaedics and create a sustainable training model for undergraduate students, we created an educational and translational research pipeline. This pipeline was created using the Vertically Integrated Projects (VIPs) course as a framework. The intended goal of a VIP is to have teams of students from various disciplines and ages work over several semesters to learn theoretical concepts of biomaterials, apply them to real research projects, and train younger students to do the same.[2] VIPs generally start early in an undergraduate student's academic career and are focused on exploring problems of external value. However, orthopaedic-based biomaterial research may be a more niche and complex field to have younger students join. To address this, short-term, hands-on inquiry-based learning (IBL) biomaterial modules are employed to capture a student's initial interest. Following this, students join the VIP and work as partners in education with more senior researchers to develop new IBL modules, while gaining confidence in their design and research skills. Finally, students in the VIP transition to working on more complex translational orthopaedic-based biomaterial projects with internal and external collaborators.

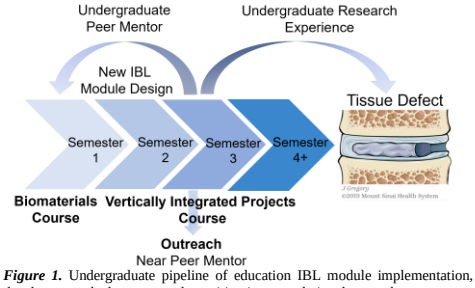

Figure 1. Undergraduate pipeline of education IBL module implementation, development, deployment, and transition into translational research

METHODS: A pipeline for orthopaedic biomaterials research training was created by utilizing the VIP framework alongside the development and execution of educational modules by undergraduate students (**Figure 1**). The first semester of the pipeline occurs in a biomaterials course, where students perform hands-on, IBL experiments. Subsequently, those interested in pursuing high level orthopaedic-based biomaterials research formally enter the pipeline in their second semester, when students join a VIP course. During this semester, students design new IBL modules for their peers in the biomaterials course. In the third semester and onward, students will (1) act as undergraduate peer mentors to help implement the IBL modules they have designed, (2) adapt and run IBL modules for K-12 STEM outreach, and (3) join translational orthopaedic-based biomaterial research projects with internal and external research collaborators.

The efficacy was assessed for both the IBL modules and the VIP experience using pre/post-tests and/or pre/post-surveys, as well as scholarly publications or presentations (**Table 1)**. For each IBL module, pre/post-tests questions are designed by the authors, including undergraduate students developing the module, to explore module impact. Pre/post-survey questions for the IBL modules come from the Scientific Literacy and Student Value in Inquiry-guided Lab Survey (SLIGS), which is a validated survey to assess scientific literacy and avoid reporting bias.[3,4] For the assessment of the student's experience in the VIP pipeline, questions from the validated Undergraduate Research Student Self-Assessment (URSSA) survey are given[5]. Students in the biomaterials course are asked to take the URSSA survey at the beginning of the course (pre-survey) and at the end of the course (post-survey). Subsequently, students are asked to take the same survey at the end of every semester (longitudinal post-survey) in the VIP course. All questions were approved by The Cooper Union IRB.

Table 2. Assessment strategy to evaluate the long-term efficacy of the proposed education pipeline

Assessment Tool	Outcome Assessed
Pre/post tests of IBL modules	Impact of specific IBL module on scientific knowledge
SLIGS pre/post survey of IBL modules	Impact of specific IBL module on attitude toward science
URSSA pre/post survey	Impact of VIP as a mechanism for long-term training of next generation scientists
Scholarly publications/presentations	Impact of pipeline on the scientific community

RESULTS: Over three years, 11 students out of 51 students who were enrolled in the Biomaterials course have participated in the full biomaterials track in the VIP pipeline. In the area of IBL module development and deployment, students in the full pipeline have been co-authors on two peer-reviewed manuscripts, three conference presentations, and two conference posters. For those students who continued to pursue the orthopaedic-based biomaterials research, students have been co-authors on one peer-reviewed manuscript, four translational conference presentations, and eight conference posters.

The efficacy of the educational modules was observed due to significant learning gains found in all the modules developed for undergraduate and outreach students[6,7]. The URSSA data collection is ongoing and assessment of the overall pipeline is a work in progress. Anecdotally, the URSSA shows a trend toward a positive experience and more confidence in STEM research as compared to the control cohort students who enroll in the VIP course without taking the Biomaterials course and/or who do not work on educational modules. More data over a longer period is needed to assess meaningful impacts on the educational value of this approach.

DISCUSSION: This study evaluated if using IBL modules has a synergistic effect in advancing students to higher level VIP studies and eventually into orthopaedic biomaterials research positions. IBL modules create early educational experiences to capture student interest. Including students in the design of new IBL modules offers a lower stakes experimental design experience with senior researchers. A hands-on course that includes IBL modules combined with the VIP model creates a pathway for students to learn proper experimental design and gain confidence in their ability to contribute to higher level translational research with senior researchers within and outside their institution. The IBL modules are a useful tool in that they are designed for students to learn how to develop their own experiment in the way a scientist works, however, they are short-term without repeated experiences[8] Meanwhile, deeper Undergraduate Research Experiences (UREs) are more commonly part of highly competitive Research Experiences for Undergraduate (REU) programs. These experiences serve a very limited number of students, which are high-intensity, but of short-duration typically lasting ~6-8 weeks. The VIP model is an important innovation that addresses both issues, which engages more students in research than REU programs allow, and by enabling these students to participate in research related experiences long-term over multiple semesters. This education model utilizing existing biomaterials courses, IBL, and VIP experiences, has already had a positive impact on many undergraduate students who have joined translational research projects, contributed to scholarly publications, and pursued graduate work in a field related to orthopaedic biomaterials.

SIGNIFICANCE: This study describes a training pipeline where students can gain skills, knowledge, and confidence in a hands-on way with short-term and long-term experiences required to train the next generation to tackle complex orthopaedic-based biomaterial projects that improve musculoskeletal health.

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